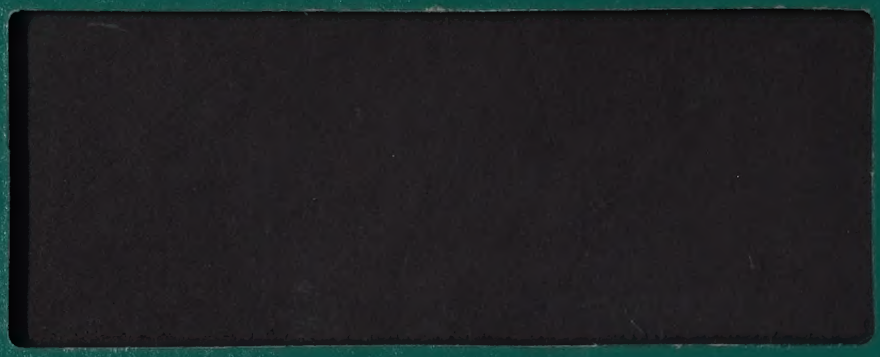
INSTRUCTION BOOK
MODEL 75A-S8
CAPACITANCE BRIDGE
(After Serial #328)

Boonton ELECTRONICS Corporation
MORRIS PLAINS, NEW JERSEY



SERIAL NO. 427

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(After Serial #328)

The Model 75A-S8 Capacitance Bridge has all of the basic features of the Model 75A, plus provisions for biasing the component under test with DC from internal supplies, or from an external source. Bias may be applied only when making "DIRECT" capacitance measurements. The circuit modifications used normally limit operation to 1 MC. (whether or not bias is applied).

A switch selects internal bias of either polarity, no bias, or external bias. The level of the internal bias is continously adjustable from 0 to +125V or -5V, using the ADJUST control.

Internal bias voltage and current may be monitored at the "VOLTAGE" posts and "CURRENT" jack provided (circuit improvements have eliminated all paths for the bias current except through the test).

Posts are provided to allow up to 400V at 100 ma. to be applied from an external source, but adjustment and monitoring must then be done at the source.

Boonton *ELECTRONICS* Corporation

738 SPEEDWELL AVENUE, MORRIS PLAINS, NEW JERSEY, U. S. A.

75A 1 MC CAPACITANCE BRIDGE

INSTRUCTION BOOK

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SECTION I

MODEL 75A

SPECIFICATIONS

1.1 CAPACITANCE * : 0.001 to 1000 μμf in 4 decade ranges.

Multipl'r	Cap. Range	Smallest Division	Accuracy Direct	Accuracy Grounded
1	100-1000 μμf	0.2 μμf	±(0.25%+0.5μμf)	±(0.25%+1.0μμf)
0.1	10- 100 "	0.02 "	±(0.25%+0.02 ")	±(0.25%+0.5 ")
0.01	1- 10 "	0.002 "	±(0.25%+0.005")	±(0.25%+0.5 ")
0.001	0- 1 "	0.0002 "	±(0.25%+0.001")	±(0.25%+0.5 ")

1.2 CONDUCTANCE * : 0.01 to 1000 micromhos in 4 decade ranges.

Divider	Cond. Range	Accuracy
1	100 to 1000 μmhos	$\pm(10\% + \frac{Q}{500}\% + 10\ \mu mhos)$
10	10 to 100 μmhos	$\pm(10\% + \frac{Q}{500}\% + 1\ \mu mho)$
100	1 to 10 μmhos	$\pm(10\% + \frac{Q}{500}\% + 0.1\ \mu mho)$
1000	0 to 1 μmhos	$\pm(10\% + \frac{Q}{500}\% + 0.01\ \mu mho)$

1.3 RESISTANCE *: 1000 Ω to 100 megohms in 4 decade ranges.

Multiplier		
1	1K to 10K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^3}\%)$
10	10K to 100K	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^4}\%)$
100	100K to 1 megohm	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^5}\%)$
1000	1 Megohm to ∞	$\pm(10\% + \frac{Q}{500}\% + \frac{R}{10^6}\%)$

Where R is the measured resistance in ohms.

These specifications apply to tests made at the HI and LO TEST posts. See Section V "Measuring Techniques" for limitations and tolerances applicable to remote measurements.

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1.4 OPERATING FREQUENCY

With self contained oscillator and indicator	:	1 MC ± 10 KC
With external oscillator and indicator	:	100 KC to 1 MC

1.5 Signal Level across Test (at balance)	:	Adjustable from approximately 0.02V to 3 V
1.6 Tube Complement:		1-6C4, 3-6AU6, 1-6X4, 1-0A2.
1.7 Power Requirements:		105-125V, 50-60 CPS, 30 W.
1.8 Weight:		Cabinet 32 lbs; Rack 25 lb.
1.9 Size:		11 H x 19-5/8 W x 12¾ D (Overall in cabinet)
		10½ x 19 x 9¾ depth behind the panel (rack mounted)

SECTION II

GENERAL DESCRIPTION

The Model 75A is an accurate, stable, and sensitive Capacitance Bridge, designed primarily to meet the need for precise measurements at a frequency of one megacycle. Either Direct or Grounded measurements may be made.

The basic virtues of its 100 KC equivalent, the BEC Model 74C, have been retained - namely, direct reading dials, self contained oscillator and indicator (for 1 MC operation), and power supply, excellent resolution and sensitivity, a high order of accuracy in measuring very small capacitance, and provision for differential measurements.

The versatile design additionally allows it to be used with an external oscillator and indicator at any frequency between 100 KC and 1 MC.

Provision for varying the level of the 1 MC test signal is standard. A modified version of the 75A (designated the 75A-S8) is available that provides a built-in adjustable D.C. bias for measuring the direct-capacitance of voltage variable semi-conductor diodes and other voltage sensitive capacitors.

SECTION III

DIRECT-CAPACITANCE VS. GROUNDED CAPACITANCE

Direct-capacitance is the capacitance existing between two conducting elements, excluding all stray capacitance that may exist to other conducting elements.

Typical examples of Direct-capacitance measurements are:

1. Capacitance between the control grid and plate of a pentode vacuum tube, excluding capacitance to cathode, screen grid, or suppressor.
2. Capacitance between any two conductors in a cable, excluding capacitance to all other conductors or the shield.
3. Capacitance between any two conductors of a printed circuit, excluding capacitance to all other conductors.
4. Capacitance between any two windings of a transformer, excluding capacitance to all other windings or shields.

Grounded capacitance is the capacitance existing between two conducting elements when one element is grounded, and includes all stray capacitance from the high side of the element to ground, either directly or by way of adjacent elements. For this reason, a Grounded capacitance reading will always be greater than a Direct-capacitance reading and will depend upon the proximity of the chassis, adjacent components, and measuring technique.

SECTION IV

OPERATING PROCEDURE FOR DIRECT OR GROUNDED MEASUREMENTS

4.1 SET UP AND ZERO BALANCING

1. Turn the power switch to ON. Select the desired method of capacitance measurement and set the selector switch to either GROUNDED or DIRECT. (See Section III).
2. Set the conductance range selector switch (marked DIVIDE G/ MULTIPLY R) to 1,000.
3. Set the MULTIPLY C switch to a position indicated in Table I on page 6.
4. Set the CONDUCTANCE dial to zero.
5. Set the CAPACITANCE dial to zero. (Both vernier and counter dials should read zero).
6. If they are required, connect test leads or fixture. (IMPORTANT: Read Section V "Measuring Techniques" before proceeding).
7. Adjust zero balance controls (located to the right of the main CAPACITANCE and CONDUCTANCE dials) until the NULL INDICATOR meter reads zero. FINE capacitance zero control should be set with pointer in vertical position before adjusting COARSE control. INDICATOR SENSITIVITY control should be set to approximately three o'clock. Too high a control setting will result in unnecessary difficulty in obtaining a null indication: too low a setting will reduce measuring accuracy.

TABLE I

Capacitance Range	"MULTIPLY CAPACITANCE" Control Setting
1,000 - 100 μμf	1
100 - 10 μμf	0.1
10 - 1 μμf	0.01
1 - 0 μμf	0.001

4.2 MEASURING

1. Connect test specimen to the HI and LO TEST posts (to test leads or fixture, if used), utilizing appropriate techniques as described in Section V.

2. Adjust CAPACITANCE and CONDUCTANCE dials until meter indicates best null. For best accuracy the null should obtain between 100 and 1,000 on both the CAPACITANCE and CONDUCTANCE dials. If it appears above or below these values, the next indicated MULTIPLY CAPACITANCE and/or DIVIDE G/MULTIPLY R range should be used.

NOTE:

Whenever the capacitance or conductance ranges are changed, the capacitor to be measured must be disconnected and the bridge zero balanced as detailed in paragraph 4.1.

4.3 INTERPRETING READINGS

1. After balancing both capacitance and conductance to a satisfactory degree of precision, the capacitance of the test specimen is determined directly from the CAPACITANCE dial reading, multiplying by the decimal factor indicated on the MULTIPLY C knob.

2. The conductance of the test specimen is found be dividing the reading indicated on the G scale of the conductance dial by the factor indicated on the DIVIDE G/MULTIPLY R dial. On the X1 Capacitance Range a correction factor for conductance must be taken into account as shown in Figure 1, Page 7. Red dial markings extending from zero

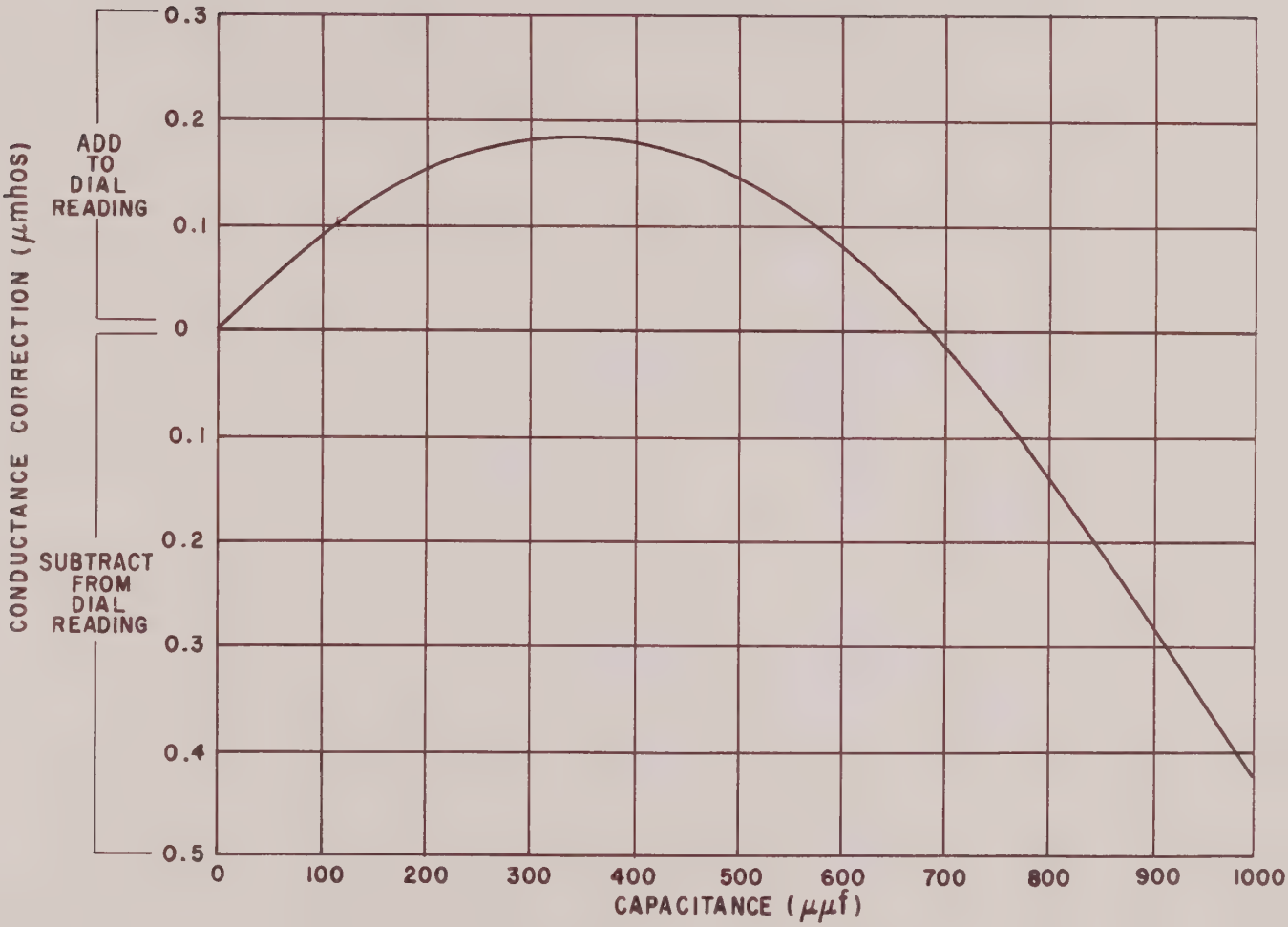

FIGURE 1

CONDUCTANCE CORRECTION FOR X1 CAPACITANCE RANGE

75A IMC CAPACITANCE BRIDGE

to minus 100 have been provided to facilitate measurements when the null is obtained with the CONDUCTANCE dial below zero.

3. Except on the X1 capacitance range, the equivalent shunt resistance is determined by multiplying the reading indicated on the R scale by the factor shown on the DIVIDE G/MULTIPLY R dial. On the X1 capacitance range the most accurate procedure is to determine the conductance as outlined in 4.3.2, then divide that figure into 1 to obtain the equivalent shunt resistance. ($R = \frac{1 \times 10^6}{G}$ where G is in micromhos).

4. The Q and Dissipation Factor, D, of the test sample may be computed from the following formulae:

$$Q = \frac{2\pi fC}{G}$$

At 1 MC

$$Q = 6.28\,\frac{C}{G} \qquad D = \frac{1}{Q}$$

Where C = test specimen capacitance in μμf.
G = test specimen conductance in micromhos.
f = frequency in megacycles.

SECTION V

MEASURING TECHNIQUES (See also Appendix A)

5.1 GENERAL

When using a test frequency of 1 MC, the effect of added lead length between the bridge and the test specimen cannot be neglected. The resulting error is primarily due to the lead inductance and resistance.

For capacitance values above about 50 μμf, increased lead length produces higher readings of both capacitance and conductance. Using the Direct method of measurement and with RG-58/U coaxial cables connecting the test specimen to the bridge, each foot of extension of the two leads will increase the readings approximately as given in Table II.

TABLE II

Capacitance to be measured	Approximate increase in reading for 1 ft. extension of test leads using RG-58/U coax. cables only.	
	C	G
1000 μμf	+ 0.8% (8 μμf)	+ 4 μmhos
500 μμf	+ 0.4% (2 μμf)	+ 1 μmho
100 μμf	+ 0.1% (0.1 μμf)	+ 0.05 μmho

Below 50 μμf the error due to lead inductance and resistance becomes relatively small, and the principal effect of remote testing is the reduction of sensitivity owing to the shunting effect of the coaxial lead capacitance. In general, up to three ft. of RG-58/U cable extension may be used without noticeable effect.

Whenever feasible, the Direct method of measurement should be used because it greatly reduces hand capacitance effects as well as the test specimen position error which are basic limitations when making grounded measurements.

5.2 DIRECT-CAPACITANCE MEASUREMENTS

1. If measurements are to be made at the HI & LO TEST binding posts, the test specimen should be connected as close as possible to these posts. All other conductors in the immediate vicinity of the elements under test must be connected to ground using the GND binding post on the front panel.

   In many cases it may be more convenient to insert the wire leads of the test specimen directly into the center conductor receptacle of the HI & LO coaxial TEST jacks. This is particularly useful with smaller mica, ceramic or voltage variable types of capacitors and has the advantage that the outer shell of each jack shields the leads from each other for much of their length.

2. When measurements are to be made at the end of coaxial cables the following procedure should be used:

   Connect the coaxial cables to the BNC HI & LO TEST receptacles and the center conductor of the LO cable to the test specimen. If other conductors are to be grounded, the shield braid of the coaxial cables may be used as a convenient ground connection. Keep the exposed portion of the center conductor of the HI cable away from the test specimen, and balance the bridge as described in paragraph 4.1 (Section IV). (1)

   Connect the HI coaxial cable to the test specimen and measure.

   (1) The small offset of both capacitance and conductance zeros that results when coaxial cables are connected to the TEST receptacles is normal when operating at 1 MC. If the bridge is operated at 100 KC (as in the 74C), this effect is negligible.

When measuring small capacitance, the length of unshielded test lead should be kept to an absolute minimum ($\frac{1}{8}$ inch or less) for greatest accuracy. Also, the test leads should be kept as far as possible from the field of the capacitance under test. In some cases it may be necessary to provide a jig for connection purposes that will completely shield and eliminate the test lead capacitance.

5.3 GROUNDED CAPACITANCE MEASUREMENTS

Grounded capacitance measurements are inherently less accurate than Direct-capacitance measurements owing to unavoidable stray capacitance variations between the HI test lead and ground.

Although these variations may amount to 1 μμf or more, it is usually possible to reduce this uncertainty to less than 0.5 μμf by using the following procedure when preparing a test specimen:

1. Connect the ground side of the test to the LO binding post using a short length of wire.

2. Connect a short length of bare tinned copper wire to the HI binding post. Bend this wire so it approaches the test sample perpendicularly and is spaced away from all surrounding objects as much as possible. The free end should be spaced approximately 1/4 inch from the high terminal of the sample for bridge zero balance adjustments. The final measurement is made with this wire connected to the test specimen.

Contact fixtures may be used for production testing provided their residual capacitance does not exceed the range of the COARSE and FINE controls (approx. 10 μμf).

5.4 DIFFERENTIAL MEASUREMENTS

In addition to the normal TEST connections on the front panel, BNC receptacles marked STANDARD ARM have been provided for access to the arm of the bridge opposite that to which a test specimen is connected.

For either differential or temperature coefficient measurements the reference capacitor is connected to the STANDARD ARM via the BNC receptacles and the test specimen to the TEST BNC receptacles. It is usually desirable to keep the connecting coaxial cables of equal lengths to both capacitors.

If the reference capacitor is adjusted at the start of the test to equal the one being tested, the bridge can then be set to a capacitance range that will give the desired resolution. For example, if a 100 μμf ceramic capacitor with a negative T.C. of 300 P.P.M./°C is to be tested to verify its T.C., a set up can be made with an adjustable air trimmer connected to the STANDARD ARM cables, and the ceramic capacitor connected to the TEST cables. The ceramic capacitor may be in a temperature chamber while the air trimmer is kept at a fixed temperature.

The capacitance of the air trimmer can now be set to equal that of the ceramic, and the bridge switched to the X.01 or X.001 capacitance ranges depending on the desired range of capacitance change to be observed. If the X.001 range is selected and the T.C. is nominal, a 30°C change of capacitor temperature should result in a 1 μμf capacitance change (full scale deflection). Alternately, if the X.01 range had been selected, coverage would have been 1/10 of full scale.

With the connections previously described, the bridge reading will be direct sensing; that is, an upscale reading indicates an increase of capacitance of the test specimen.

When testing capacitors of 10 μμf or less for T.C., an external capacitor on the STANDARD ARM is unnecessary since the C ZERO COARSE and FINE controls can be used for that purpose.

When the highest possible stability is required for critical T.C. measurements, it is best to leave the bridge on continuously.

SECTION VI

MAINTENANCE

6.1 GENERAL

This capacitance bridge has been carefully calibrated at the factory against three-terminal capacitance standards certified by the National Bureau of Standards. Unless comparable standards are used, re-calibration of this instrument by other than the manufacturer is inadvisable.

Calibration is not affected by removing the bridge from the cabinet or by replacing tubes. The shield over the bridge section, however, should not be removed.

6.2 TUBE REPLACEMENT

Tubes need not be replaced until they cease to perform satisfactorily. If there is a question as to performance, new tubes may be substituted to check for improvement, or they may be checked on any good tube tester.

No tube selection is necessary.

The 6C4 1 MC oscillator tube is accessible by removing the top cover of the oscillator shield. When replacing this cover be sure to tighten the holding screws to prevent leakage.

6.3 NORMAL OPERATING VOLTAGES.

Table 4

Conditions:

115V 60 cycle line input.

Bridge balanced.

AC/DC Multimeter with d-c sensitivity of 20,000 ohm/V.

RF Voltmeter, such as Boonton ELECTRONICS Corp. Model 91C.

Test Points	Normal Rdg.	Notes
V5 (6X4) Pin 7 (cathode) to chassis	270-290V D.C.	
V6 (0A2) Pin 5 (plate) to chassis	145-155V D.C.	
V1 (6C4) Pin 5 (plate) to chassis	220-240V D.C.	OSC level switch on HI, OSC LEVEL ADJUST fully clockwise.
V2, 3,4 (6AU6) Pin 5 (plate) to chassis	230-260V D.C.	
" Pin 6 (screen) to chassis	130-150V D.C.	
" Pin 3 (heater) to Pin 4	6.0-6.6V A.C. (60 cycle)	
J1 Oscillator output.	1.0-1.5V A.C. (1 MC)	

6.4 1 MC OSCILLATOR AND INDICATOR CHECKS AND ADJUSTMENT.

1. Overall check.

The correctness of operation of the oscillator and indicator may be conveniently tested by an overall check of NULL INDICATOR meter deflection for a known amount of bridge unbalance.

To do this, switch to DIRECT, X1000, and X.001. Turn the INDICATOR SENSITIVITY control fully on and the CAPACITANCE & CONDUCTANCE dials to zero. Carefully balance the bridge, using the C ZERO COARSE and FINE, and R/G ZERO controls.

Turning the CAPACITANCE dial 1 μμf (effective change being 0.001 μμf) in either direction from balance should produce an increase in NULL INDICATOR meter reading of at least 20 μa.

If less change in meter reading obtains, the oscillator and/or indicator may require re-alignment.

2. Alignment

To re-align the oscillator and indicator circuits, switch to DIRECT, X1000, and X1. Turn the CAPACITANCE & CONDUCTANCE dials to zero and the INDICATOR SENSITIVITY control fully on. Balance the bridge using the C ZERO COARSE and FINE, and R/G ZERO controls.

Now, unbalance the bridge for a meter reading of about 15 μa, and then adjust the OSC FREQ control for maximum meter reading. An appreciable increase in meter reading may indicate that the insensitivity has been overcome which can readily be determined by repeating step 6.4.1 "Overall Check".

If the procedure of 6.4.2 did not improve the sensitivity, the indicator should be checked, peaking each circuit of T4, T5, T6, and T7 for a maximum meter reading (keep the meter at about 15 μa by nearly balancing the bridge). Repeat step 6.4.1.

The final alignment step requires an RF Voltmeter suitable for use at 1 MC. Switch the OSC LEVEL toggle switch to the LO position. Connect the voltmeter between the LO TEST post and the ground post, and adjust the oscillator FILTER ADJ. control for maximum reading on the RF voltmeter. The reading should be about 1V RMS. Restore the OSC LEVEL switch to the HI position.

Repeating step 6.4.1 should now give at least a 20 μa/dial μμf reading on the NULL INDICATOR meter.

3. Oscillator Frequency

The oscillator frequency has been factory adjusted to be within a few KC of nominal. If it is necessary to re-adjust the frequency, it should be done with the oscillator connected normally to the bridge, which has been allowed to warm up for

at least one half hour.

Any standard method of determining frequency may be used, such as a frequency counter or crystal calibrator.

4. Indicator Sensitivity

Indicator sensitivity can be checked with a well shielded Signal Generator having low output impedance and a calibrated attenuator. Connect the generator by coaxial cable to J2. With the INDICATOR SENSITIVITY control fully clockwise, determine the input level required for a NULL INDICATOR meter reading of 25 µa. Normal input level is approximately 0.5 microvolts.

6.5 BRIDGE CIRCUIT

1. Conductance

To check the operation of the conductance measuring circuit, first set the DIVIDE G/MULTIPLY R and the MULTIPLY C switches at 1 and the CAPACITANCE dial at zero. The R/G ZERO control should be set near mid-rotation (approx. $2\frac{1}{4}$ turns from either stop).

Next, balance the bridge using the COARSE and FINE capacitance controls and the main CONDUCTANCE dial. Balance should be reached with the CONDUCTANCE dial at or near zero (within ONE DIAL DIVISION, i.e. $\pm$ 10 µmhos).

With the CONDUCTANCE dial at the setting that yields balance on the X1 DIVIDE G/MULTIPLY R range, it should be possible to achieve a conductance balance on other DIVIDE G/MULTIPLY R ranges, in either DIRECT or GROUNDED positions of the GROUNDED/DIRECT switch, using only the R/G ZERO control and the COARSE and FINE capacitance controls. (Do not connect any cables or test fixtures to the bridge while making this test).

A quick test of operation on all DIVIDE G/MULTIPLY R ranges may be performed using 1K, 10K, 100K and 1 megohm, 1/4 watt, $\pm$ 1% deposited carbon resistors.

a. First, set up the bridge as detailed in the first two paragraphs of 6.5.1. Then, connect the 1K resistor between the HI & LO TEST posts and balance the bridge using the CONDUCTANCE and CAPACITANCE dials. Read the indicated value on the CONDUCTANCE dial.

b. Remove the 1K resistor, switch to "10" on the DIVIDE G/ MULTIPLY R control, turn the main CAPACITANCE and CONDUCTANCE dials to zero and re-balance using the R/G ZERO control and the COARSE and FINE capacitance controls. Connect the 10K resistor and again balance using the CONDUCTANCE and CAPACITANCE dials. Read the indicated resistance value on the CONDUCTANCE dial and multiply by 10.

c. Repeat the procedure on the X100 and X1000 ranges using the 100K and 1 megohm resistors, respectively. In all cases, readings should fall within ± 11% of full scale on the CONDUCTANCE dial.

6.5.2 Capacitance

The variable capacitor has been very accurately balanced and adjusted at the factory to insure tracking to the CAPACITANCE dial calibration. This operation requires special equipment and techniques, and should not be attempted in the field.

If it is necessary to standardize the capacitance calibration (by measuring capacitance standards), the bridge should be operated at 100 KC with an external oscillator and indicator. At this frequency the effects of lead inductance and cable capacitance are greatly reduced.

The calibration obtained by standardizing at 100 KC will hold for 1 MC measurements at the HI & LO TEST posts, with the exception that on the X1 capacitance range, only, slightly greater accuracy can be secured by applying the following corrections for the effects of internal lead inductance:

Table 5

CORRECTION FOR INTERNAL INDUCTANCE: X1 CAPACITANCE RANGE ONLY

CAPACITANCE DIAL RDG (μμf)	50	100	200	300	400	500	600	700	800	900	1000
CORRECT RDG BY ADDING: (μμf)	+0.03	+0.2	+0.25	+0.05	0.0	-0.05	-0.2	-0.4	-0.7	-1.0	-1.6

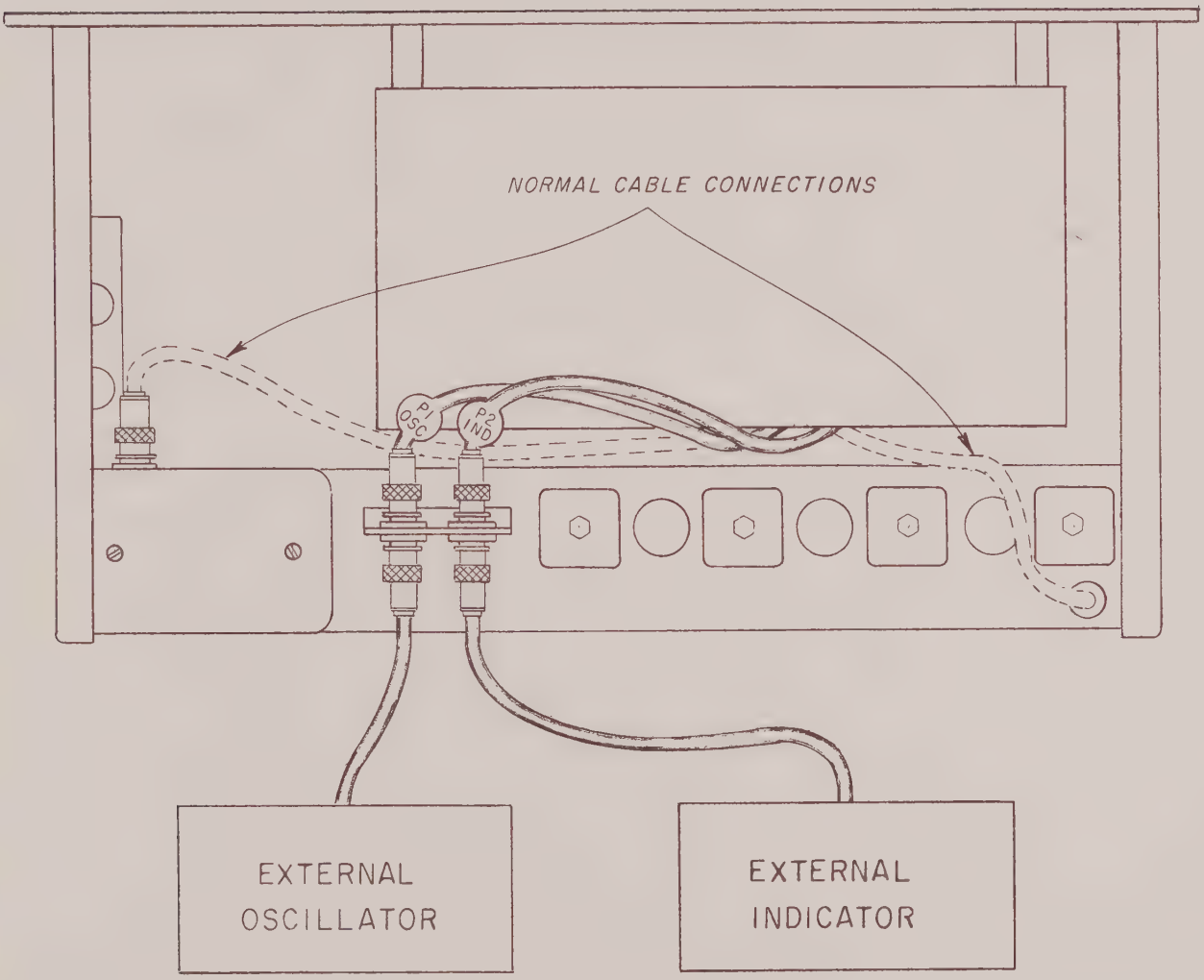

FIGURE 2

CONNECTIONS FOR USE WITH EXTERNAL OSCILLATOR AND INDICATOR

7.1 OSCILLATOR REQUIREMENTS

An external oscillator to be used with the 75A should cover the desired operating frequency, be capable of delivering at least 1V into a 16 Ω load, have a low internal impedance, and be well shielded to avoid direct pick-up by the indicator.

Harmonic distortion need not be very low except when the 75A is to be used for testing semiconductors. For this use it should not exceed 1%, and preferably 0.1%.

7.2 INDICATOR REQUIREMENTS

An external indicator for use with the 75A must have high gain at the test frequency, good signal-to-noise ratio, and good shielding against external pick-up. If a receiver is used, it may have a B.F.O. for the indication of an unmodulated signal, or may be used with a tone modulated oscillator.

Although it may be omitted in many cases, a simple matching transformer is desirable between the low impedance of the bridge output transformer and the receiver input. Proper matching will increase the usable indicator sensitivity and give greater measuring resolution.

SECTION VIII

WARRANTY

Boonton ELECTRONICS Corporation guarantees to the original purchaser that each instrument it manufacturers be free from defects in material and workmanship for a period of one year after date of initial shipment. Our liability is limited to repairing or replacing any defective part with the exception of vacuum tubes, panel lamps, fuses, choppers, and batteries. The warranty lapses if, upon our examination, we judge that the instrument has been abused in any way.

PROCEDURE TO FOLLOW WHEN INSTRUMENT IS DEFECTIVE

1. Call our plant or our representative nearest you. A simple solution may result from discussion of the problem with our trained personnel.
2. If the fault is not readily eliminated, prepare the instrument for return to us. Pack carefully in a sturdy container using several inches of shock absorbing material on all six sides of the instrument. Include all probes, cables, or accessory units. On all paper work pertaining to the returned instrument, note the model and serial number and state briefly the details of the fault. Ship to us transportation charges prepaid.
3. If the instrument is within the warranty, we will repair and return to you transportation charges prepaid. If the instrument is beyond the one year warranty period, we will repair and return it unless approval on a cost estimate is requested. If the instrument is within the one year warranty period, but our examination reveals abuse, we will await approval of our cost estimate before proceeding with repairs.

SECTION IX

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APPENDIX A

Some Comparisons Between Capacitance Measurement Errors at 100 KC and 1 MC

A. General:

Use of 100 KC as the test frequency offers considerable advantage in several areas which include:

1. Measurements above 100 pf, whether remotely or at the bridge.
2. Practically all remote measurements when appreciable capacitance exists between either HI or LO TEST post and ground.
3. All measurements when the test itself is not a simple two-terminal capacitor, but has capacitance from either or both terminals of the test to other elements.

Figure A-1 shows the recommended set-up procedure for making remote measurements.

B. Errors due to Lead Inductance

Above about 100 pf the use of 100 KC as the test frequency greatly reduces the error due to the inductance of the leads connecting the bridge to the test.

Graph 1 shows the added error due to lead inductance when 1 foot long RG-58/U coaxial cables are added between the bridge and the test capacitor. It is apparent that at 100 KC this error is about 100 times less than at 1 MC.

It should be noted that Graph 1 does not give total measurement errors - only the increase in reading per foot of the specified coaxial cables. At 1 MC, the inductance of leads

a

internal to the bridge can and does contribute appreciable error. (See Table V, page 18 of the 75A Instruction Book for average errors due to internal inductance).*

This error, of course, is present whether open wire leads or coaxial cable are used to connect the test to the bridge.

C. Errors due to Coaxial Cable Capacitance

Below about 50 pf the capacitance between the center conductor and outer braid of the coaxial cables causes an increase in capacitance reading. This effect is generally negligible at 100 KC, but appreciable at 1 MC. Graph 2 shows the approximate magnitude of this error. Note that the error is not a constant percent-per-foot; instead it becomes greater the longer the cables.

D. Errors due to Measuring Other Than a Simple Two-Terminal Test

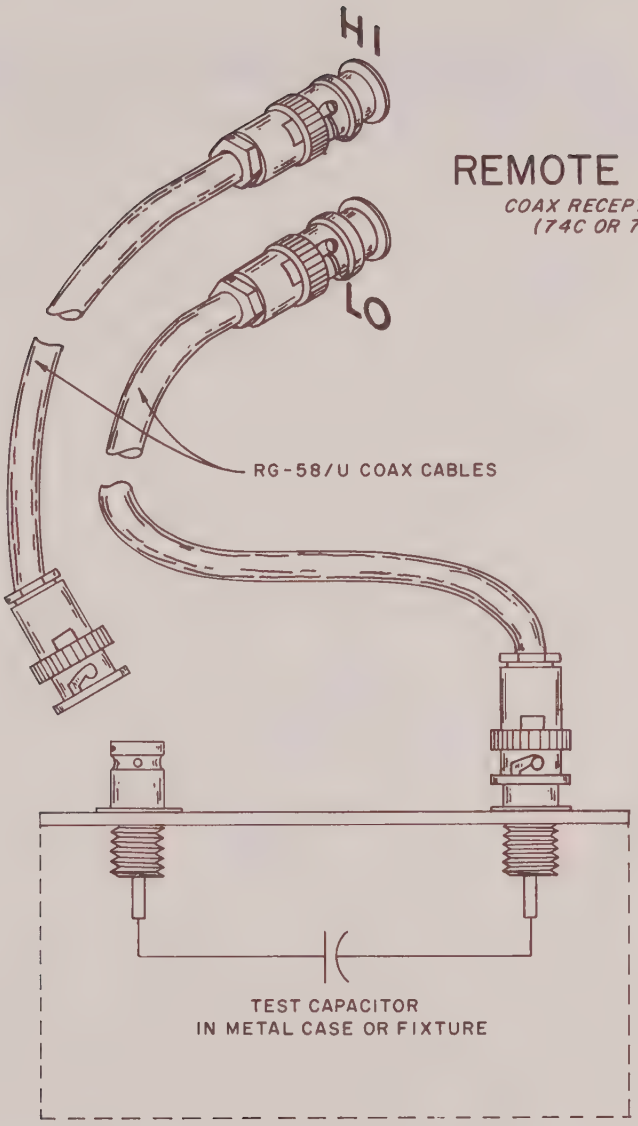
Graph 3 shows representative errors when measuring a 2.2 pf ceramic capacitor in the presence of capacitance between the LO side of the test and ground (cable braid); the HI side and ground; and with equal values from both sides to ground.

* TABLE V (FROM 75A CAPACITANCE BRIDGE INSTRUCTION BOOK)

CORRECTION FOR INTERNAL INDUCTANCE: X1 CAPACITANCE RANGE ONLY

CAPACITANCE DIAL READING (pf)	50	100	200	300	400	500	600	700	800	900	1000
ADJUST READING BY ADDING: (pf)	+0.03	+0.2	+0.25	+0.05	0.0	-0.05	-0.2	-0.4	-0.7	-1.0	-1.6

a



SETUP FOR REMOTE MEASUREMENT OF CAPACITORS USING COAXIAL CABLES (DIRECT ONLY)

PROCEDURE:

1. *Connect both cables to the bridge, and connect the* LO *cable to the case receptacle of the test that has the greatest capacitance to case (if any).*

2. *Balance the bridge*

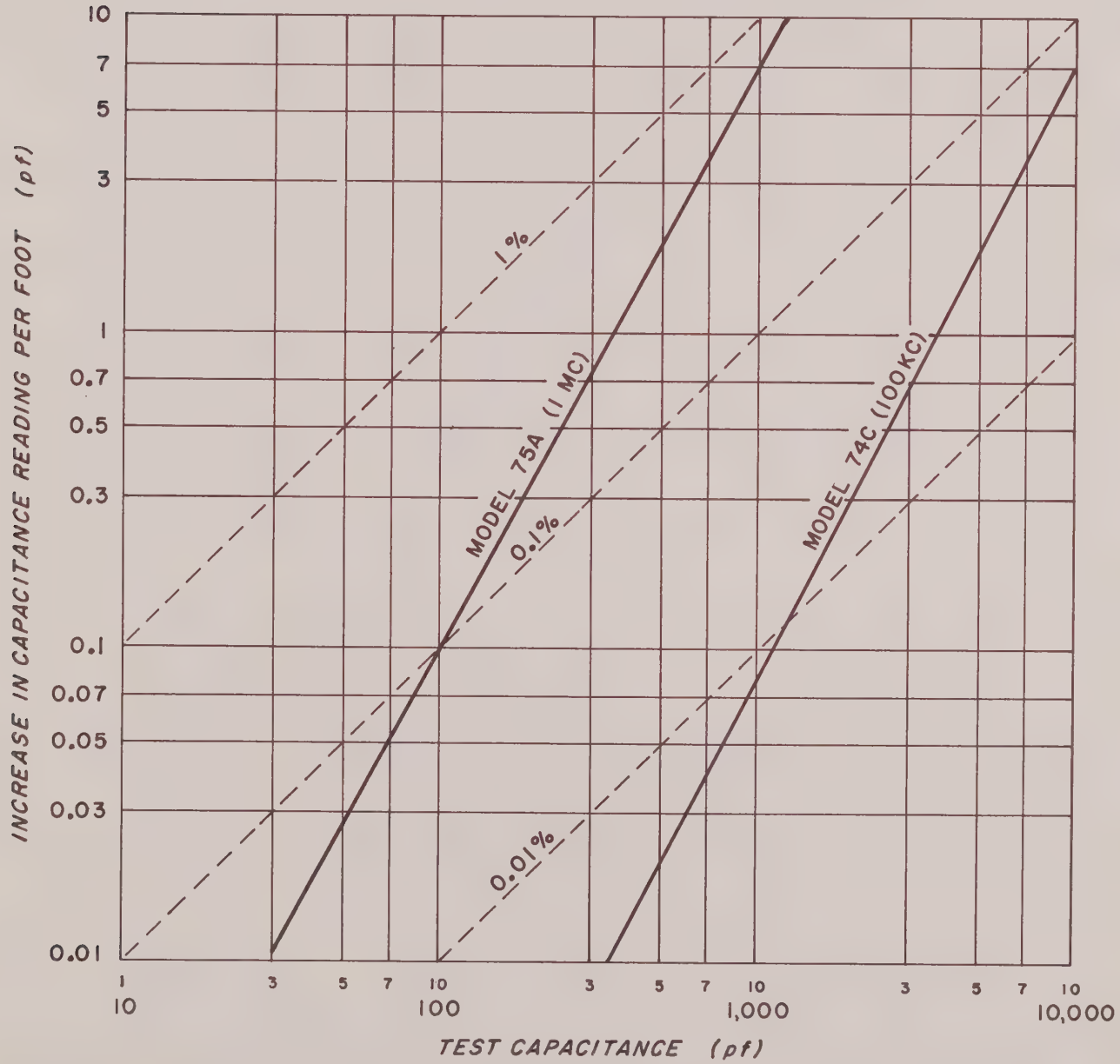
3. *Connect the* HI *cable to the other case receptacle and measure.*

Figure A1

(830,070A)

REMOTE MEASUREMENT ERROR DUE TO CABLE INDUCTANCE

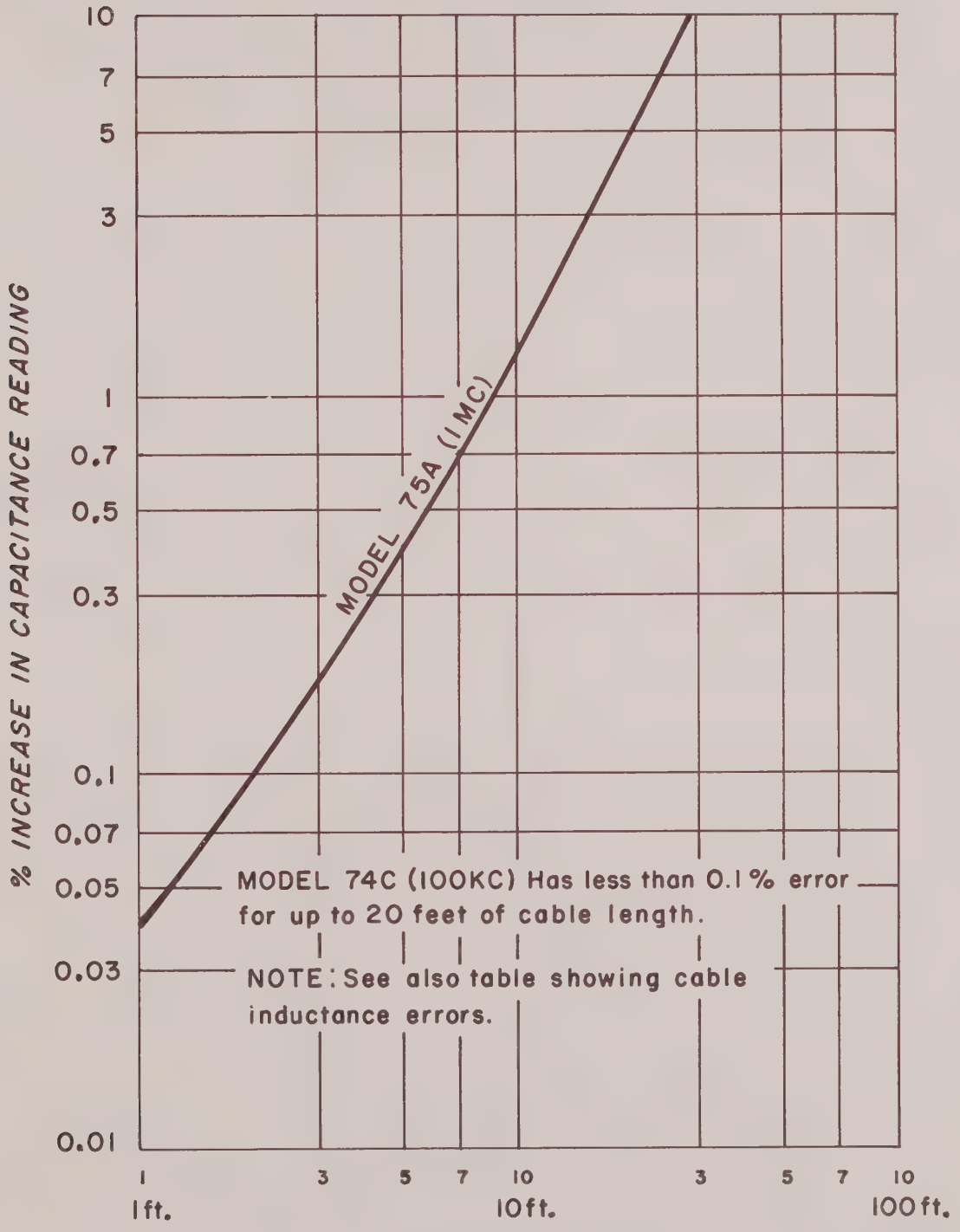
(INCREASE IN CAPACITANCE READING PER FOOT OF RG-58/U CABLES)



Graph 1

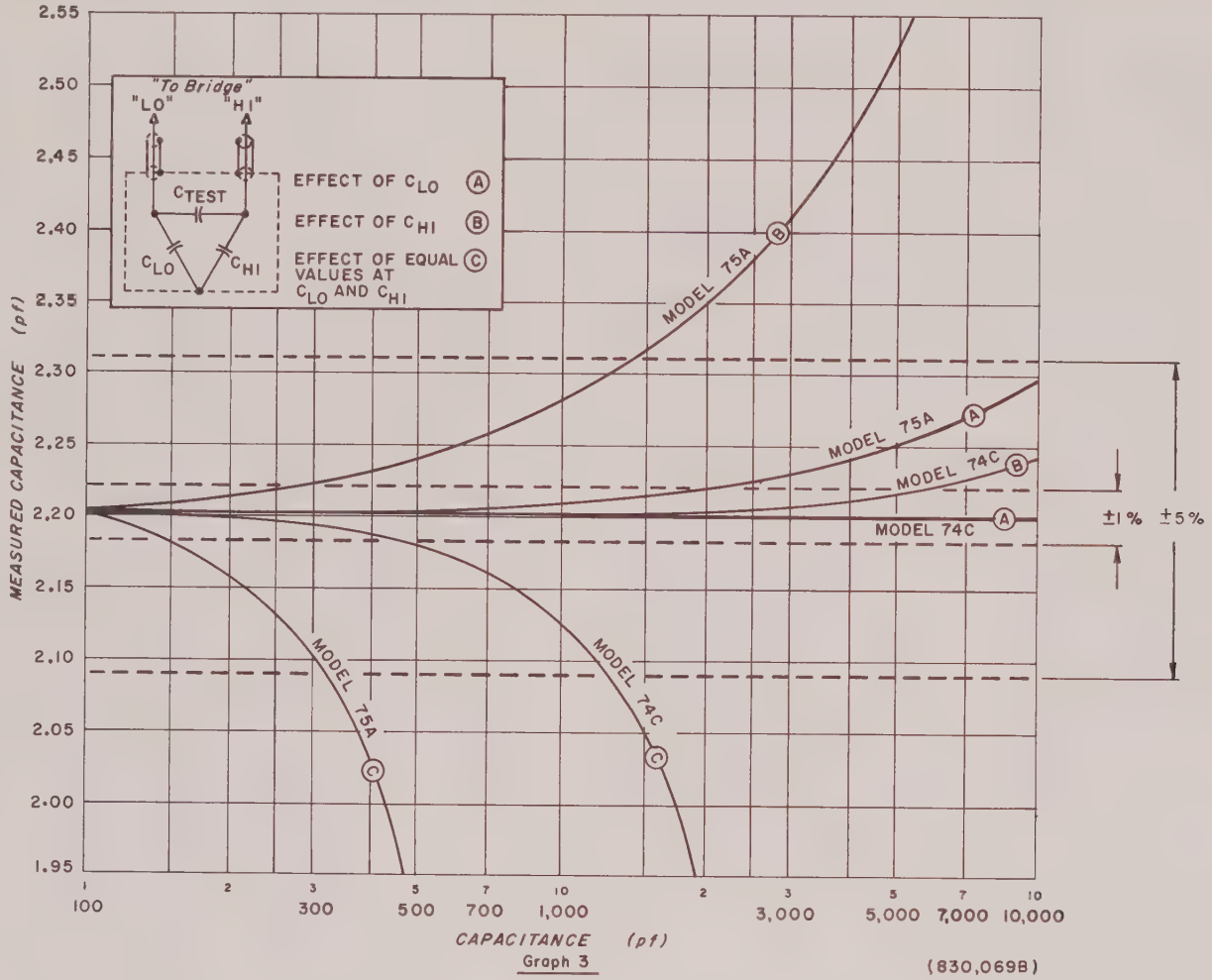
(830,067B)

REMOTE MEASUREMENT ERROR DUE TO CABLE CAPACITANCE



Graph 2 (830,068A)

REPRESENTATIVE ERRORS WHEN MEASURING A 3-TERMINAL CAPACITOR



Graph 3

(830,069B)

THE USE OF CAPACITANCE STANDARDS LARGER THAN 100 pf FOR CHECKING CAPACITANCE ACCURACY ON THE X1 CAPACITANCE RANGE OF THE 75A AT FREQUENCIES ABOVE 100 KC.

Introduction

At 1 MC, lead inductance effects become the limiting factor in making accurate capacitance measurements above approximately 100 pf. This paper offers specific suggestions for minimizing errors from this source.

In the design of the 75A, great care was taken to minimize internal inductance, with the final design having less than 0.25% error in reading between 100 and 1000 pf without the use of a correction chart, provided the test is connected directly at the HI and LO TEST binding posts or directly at the centers of the TEST coaxial receptacles. The internal inductance errors may be further minimized by applying the corrections given in Table 1.

TABLE 1

(FROM 75A CAPACITANCE BRIDGE INSTRUCTION BOOK)

CORRECTION AT 1 MC FOR INTERNAL INDUCTANCE: X1 CAPACITANCE RANGE ONLY

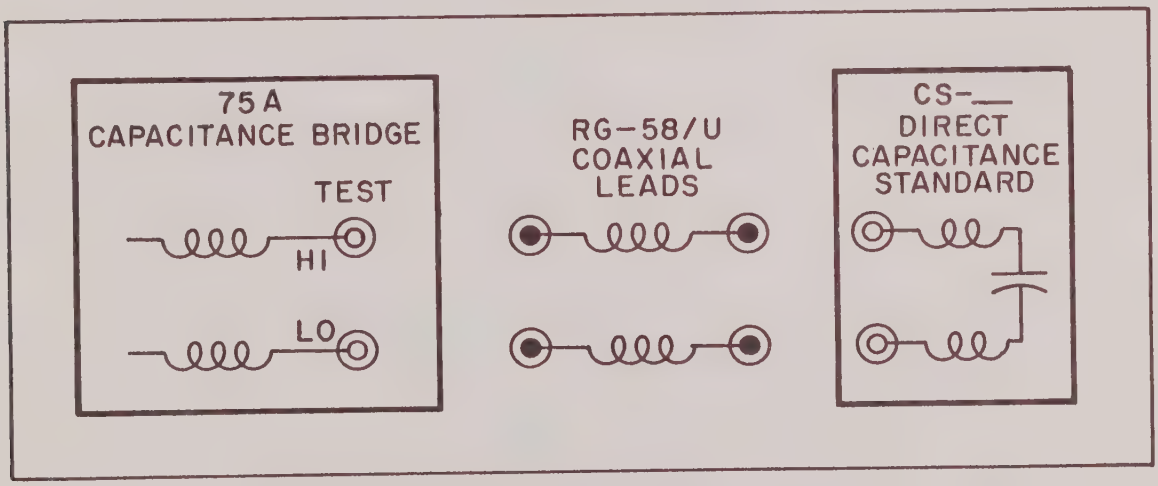
CAPACITANCE DIAL READING (pf)	50	100	200	300	400	500	600	700	800	900	1000
ADJUST READING BY ADDING: (pf)	+0.03	+0.2	+0.25	+0.05	0.0	-0.05	-0.2	-0.4	-0.7	-1.0	-1.6

It has been our policy in the past to recommend that our 1 MC bridges be returned to us for calibration checks, since we have both the trained personnel and the specialized equipment to do an accurate job.*

When the customer elects to check the bridge calibration himself, we recommend that the X1 capacitance range (100 to 1000 pf) be checked initially at 100 KC, thus eliminating the need to consider the effects of inductance in the bridge, in the coaxial leads, or in the Standard.**

If the calibration is found to be within specifications at 100 KC it may then be checked at 1 MC, with the knowledge that differences between readings at the two frequencies are directly attributable to the effects of inductance in the bridge, the leads, or the Standard. (See Figure 1)

FIGURE 1



* Recalibration is performed for a flat charge of $ 25.00, assuming that no repairs are required.

** We can supply a suitable 100 KC unit for this purpose. It is designated "75-2A 100 KC Oscillator/ Detector Unit", and is mechanically and electrically interchangeable with its 1 MC counterpart in the 75A. It is supplied pre-aligned and ready for use without further adjustment. The price is $175.00.

Typical test results for a setup using a 75A, RG-58/U coaxial leads, and type CS-__ Capacitance Standards are given in Table 2.

Table 2

CS-__ Direct Capacitance Standard	Nameplate Value (pf)	75A CAPACITANCE READINGS USING RG-58/U COAXIAL CABLES					
		Cable Length 3-1/2 inches			Cable Length 9-1/2 inches		
		@ 100KC	@465KC	@ 1MC	@ 100KC	@ 465KC	@ 1 MC
CS-1000	1000.4	1000.1	1001.0	1003.9	1000.1	1001.7	1007.4
CS-750	743.9	743.8	744.05	745.4	743.8	744.6	747.4
CS-500	499.7	499.8	499.8	500.05	499.8	500.05	501.0
CS-300	299.7	299.85	299.8	299.6	299.85	299.9	300.0
CS-100	100.00	99.75	99.64	99.45	99.75	99.64	99.51

The comparative data in Table 2 for measurements made using 3-1/2 inch and 9-1/2 inch RG-58/U coaxial leads shows that at 1 MC it is practically impossible to measure a 1000 pf standard without incurring lead inductance errors. Each inch of increase in the length of the cables is shown to cause a 0.6 pf (0.06%) increase in the reading.

Table 3 interprets the data in Table 2 in terms of the increase in capacitance reading per inch and per foot of cable extensions. (See also Graph 1 of APPENDIX A in the 75A Instruction Book).

TABLE 3

INCREASE IN CAPACITANCE READING DUE TO INDUCTANCE OF RG-58/U COAXIAL CABLES.

Value of Capacitance Standard	At 1 MC		At 465 KC		At 100 KC
	Per ft. of cable	Per inch of cable	Per ft. of cable	Per inch of cable	
1000 pf	7 pf	0.58 pf	1.4 pf	0.12 pf	(Negligible error - no correction required)
750 pf	4 pf	0.33 pf	1.1 pf	0.09 pf	
500 pf	1.9 pf	0.16 pf	0.5 pf	0.04 pf	
300 pf	0.8 pf	0.066 pf	0.2 pf	0.017 pf	
100 pf	0.1 pf	-	-	-	

(Subtract to Correct)

To Summarize:

1. The effects of lead inductance inside the 75A are small enough that at 1 MC specified accuracy is met without using corrections - provided the capacitor to be measured is connected directly at the HI and LO TEST binding posts or TEST coaxial receptacles. If greater accuracy is required, apply the corrections given in Table 1 to correct for the internal inductance effects.

2. The capacitance accuracy on the X1 range of the 75A should preferably be checked at 100 KC.

3. For capacitance measurements at 1 MC above 100 pf, correction must be made for the effects of the coaxial leads used between the test and the bridge, and may be figured from Table 3.

An Example:

A 75A is to have its capacitance accuracy checked on the X1 Capacitance range at 1 MC, using 100, 500 and 1000 pf type CS-__ Direct Capacitance Standards connected to the bridge with 6 inch RG-58/U coaxial cables.

If no 100 KC Oscillator/Detector unit is available, a fairly accurate check can still be made by measuring the Standards at 1 MC, and applying both the corrections from Table 1 and Table 3 of this paper. The corrected readings should fall well within the bridge guarantee specifications.

(1) Standard: CS-___	"100"	"500"	"1000"
(2) Certified (Nameplate) Value of Standard	100.02 pf	499.9 pf	1000.1 pf
(3) Reading on 75A with 6" RG-58/U Coax. leads	99.8 pf	500.7 pf	1005.4 pf
(4) Correction from Table 1	+.2 pf	-.05 pf	-1.6 pf
(5) Correction from Table 3	-.05 pf	-.95 pf	-3.5 pf
(6) Net correction (4) + (5)	+.15 pf	-1.0 pf	-5.1 pf
(7) Corrected reading (3) + (6)	99.95 pf	499.7 pf	1000.3 pf
(8) Bridge Calibr. Error (7) vs. (2)	-0.07 pf	-0.2 pf	+0.2 pf
(9) Guarantee Tolerance (± 0.25% + 0.5 pf on X1 Range)	±0.75 pf	±1.75 pf	±3.0 pf

SECTION X

TABLE OF REPLACEABLE PARTS

Note:

Components in the "Bridge" unit have not been included, since in general their replacement must be followed by adjustments that require specialized equipment and techniques.

C1	Capacitor, sil. mica	56 µµf ± 1%	Arco DM15F560F
C2	Capacitor, ceramic, Zero T.C.	3.3 µµf ± .25µµf	CRL TCZ-3R3
C3,4, 5,40,41	Capacitor, ceramic	0.05 µf 0 + 100% 500 W.V.	Glenco CBM-.05-3
C6,7	Capacitor, ceramic	0.1 µf 0 + 100% 500 W.V.	" CBM-.1 -3
C8 thru 19 (in bridge)			
C20	Capacitor, sil. mica	5100 µµf ± 5%	Arco DM20F512J
C21 thru 26	" " "	200 µµf ± 5%	" DM15F201J
C27	" " "	100 µµf ± 5%	" DM15F101J
C28,30,32,34, 36,38	Capacitor, paper	0.01 µf ± 20% 400 W.V.	
C29,33,37	Capacitor, met. paper	0.1 µf ± 20% 200 W.V.	
C31,35,39	Capacitor, paper	0.05 µf ± 20% 400 W.V.	
C42	(in bridge)		
C43	(not used)		
C44	Capacitor, electrolytic	20-20 µf/450 W.V.	Mallory FP-234
D1	Diode	1N34A	
F1	Fuse	0.5A	Buss AGC-.5
L1,2	Choke, RF	2.5 mh 200 ma	Miller 6302
L3,4	Choke, Iron core, RF	55 µh 300 ma	Miller 4629
L5	Choke, power	7 hy 50 ma	Stancor C1707
L6	Choke, RF	Special	BEC 400,026

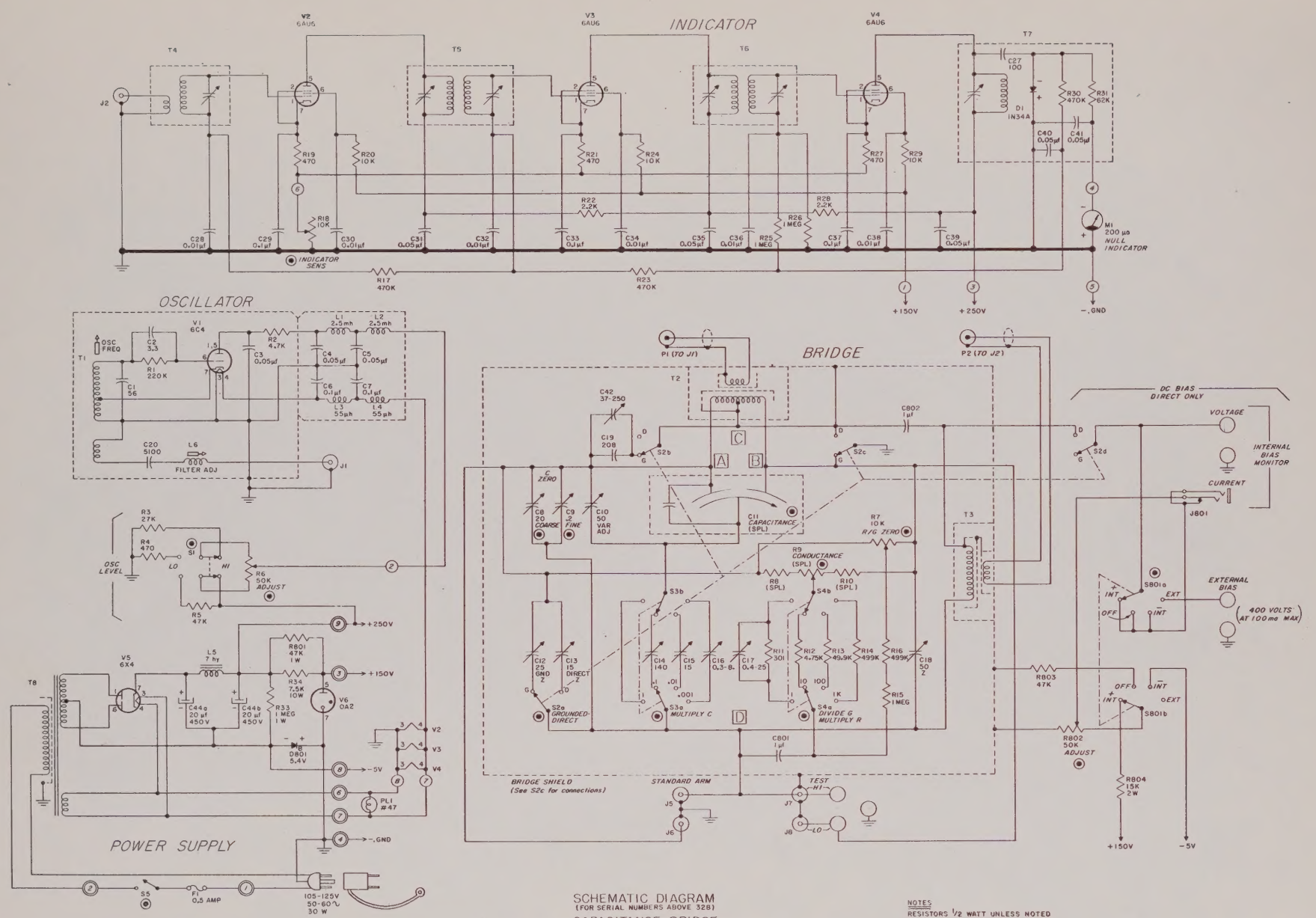
M1	Meter, Special scale	200 µa	BEC 554,116
R4,19,20,21,22,24,25,26, 27,28,29,31.	Resistor, composition	±5% ½W	AB Type EB
R1,2,17,23,30	Resistor, composition	± 10% ½W	AB Type EB
R3,5	" "	± 5% 1W	AB Type GB
R33	" "	±10% 1W	AB Type GB
R6	" variable	50K Ω 2W linear	AB Type J
R18	" "	10K Ω 2W linear	AB Type J
R34	" W.W.	7.5K Ω ±10% 10W	Mallory 1HJ 7500
R7 thru R16 (in bridge)			
R32	(Not used)		
S1	Switch, toggle	DPDT	AH&H 81027 AZ
S2,3,4, (in bridge)			
S5	Switch, toggle	DPST	Carling 216-62
T1	Transformer, Osc.		BEC 075,010
T2,3	(in bridge)		
T4	Transformer, IF	Special	BEC 075,006
T5,6	" "	"	BEC 075,007
T7	" "	"	BEC 075,008
T8	" power		Stancor PC8401
V1	Tube	6C4	
V2,3,4,	"	6AU6	
V5	"	6X4	
V6	"	0A2	

SUPPLEMENTARY TABLE OF REPLACEABLE PARTS

FOR 75A-S8 CAPACITANCE BRIDGE AFTER

SERIAL NUMBER 328

C801,C802	Capacitor, Met. Paper	(in bridge)	
D801	Diode, Zener	5.4 V ± 5% .5W	Hoffman HR 5.4
J801	Jack, Phone		Switchcraft 13B
R801	Resistor, Composit.	± 10% 1W	AB Type GB
R802	Resistor, Variable	50K Ω ± 10% Log Taper	AB Type J
R803	Resistor, Composit.	± 10% 1/2W	AB Type EB
R804	Resistor, Composit.	± 5% 2W	AB Type HB
S801	Switch, Rotary	2P4T Non-shorting	Centralab PA-2003



SCHEMATIC DIAGRAM
(FOR SERIAL NUMBERS ABOVE 328)

CAPACITANCE BRIDGE
MODEL 75A-S8
(TEST FREQ: 1 mc)

Boonton *ELECTRONICS* Corp.
MORRIS PLAINS, N.J.

830,081A

NOTES:
RESISTORS 1/2 WATT UNLESS NOTED
K=1,000
CAPACITANCE IN µµf UNLESS NOTED

⏚ PANEL GROUND
(1) PIN NUMBER ON P3 and J3
(1) PIN NUMBER ON P4 and J4
◉ PANEL CONTROL

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